THE PHOSPHATE DEPOSITS OF EGYPT

SURVEY DEPARTMENT,
EGYPT.

2nd EDITION.

CAIRO:
NATIONAL PRINTING DEPARTMENT.
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CONTENTS.

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INTRODUCTION.

The formation of the Geological Survey in Algeria led to an important discovery of phosphatic deposits by M. Thomas in 1873, which have since become of considerable commercial value, the production for 1902 being estimated at over 575,000 tons. As the rich phosphates were found to characterize a definite horizon at the base of the Eocene series, viz., the lower Suessonian, and strata of the same age were also present in Egypt, the French geologists in 1894 approached M. Fourtau as to the possibility of these deposits also occurring in this country, but his reply was a practical negative *. In 1898, the subject was re-opened, M. Thomas having suggested three localities for examination, viz.: 1. El Guss Abu Said, west of the oasis of Farafra. 2. Jebel Dwanka, or the Todtenberg, near Assiut, and 3. Wadi Tih. The nature of the beds at these points was considered by M. Fourtau †, and he rightly arrived at the conclusion that these localities were unproductive, 1st, because they were at a higher horizon than the beds in Algeria, and 2nd, because they were deep sea deposits, whereas the strata in Algeria were distinctly of littoral formation. He further suggested to meet the first objection that search would rather have to be made in the chain of hills extending between the cataract of Assuan and the oases of Doukoun and Kourkour, to the west of the Nile, there being also a hope that phosphates might yet be found below or above the *Bothriolampas abundans* zone, which is the equivalent of the *Bothriolampas Tunetana* zone of the Tunisian Suessonian.

In conclusion, M. Fourtau was inclined to believe that phosphates would be found in the Upper Cretaceous, and more especially in Dakhla, in connection with the deposits containing sharks' teeth described by Zittel in Qasr Dakhl. This remark is an interesting coincidence, as

* R. Fourtau. *Les phosphates*. Bull. Institut Egyptien, 1894.

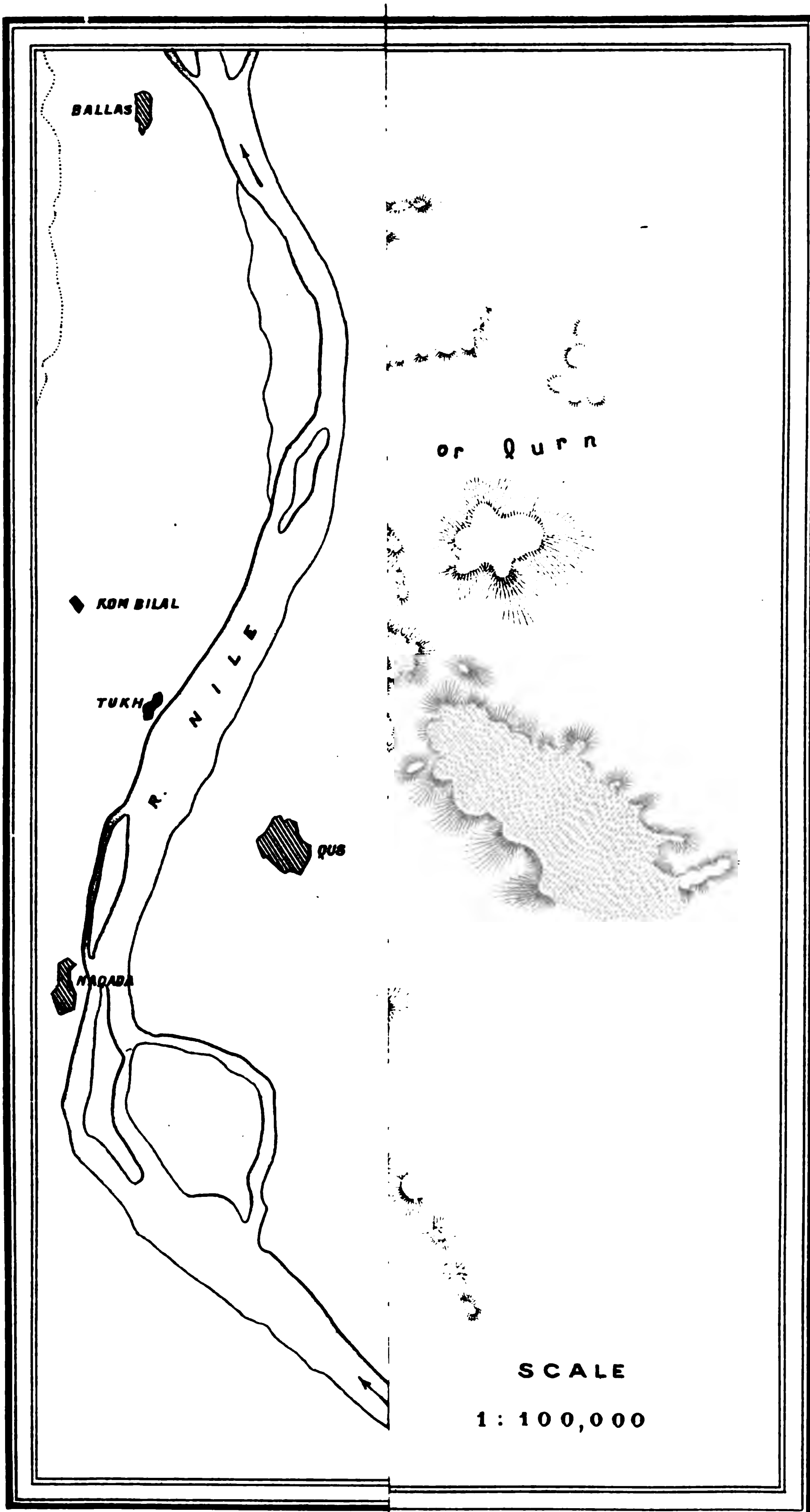
† R. Fourtau. *Les phosphates de chaux en Egypte*. Bull. Institut Egyptien, 1899.

Beadnell had in this year (1898), while working in the Dakhla Oasis, discovered the widely extended phosphate-bearing strata subsequently described. The existence of phosphatic beds in Egypt had, however, already been established by Barron's discovery (early in 1897) of beds of this nature south of Esna and also near Qift, though owing to the faulted nature of the ground, their exact age was not at that time determined. In 1898, these beds were studied by Barron and Hume in the Eastern Desert, and were shown to be present at a definite horizon in the Cretaceous series, which from Blanckenhorn's identifications of the fossils proves to be Campanian, and in 1899 Barron showed them to be present in the Campanian beds of Western Sinai. The analyses of the samples, made by Lucas in the Survey Department Laboratory, have established the fact that they contain in many instances 40-50 % of tricalcic phosphate, the general results as to distribution, nature, and possible agricultural value being discussed in the Geological Survey "Report on the Phosphate Deposits of Egypt, 1900", and in the memoirs on particular districts * †.

In the present edition it is proposed to bring the subject up to date by adding the results of analyses and investigations made since 1900, together with a section on the Algerian deposits for comparison with those of Egypt.

* H. J. L. Beadnell. *Dakhla Oasis : Its Topography and Geology.* (See especially, Chap. VII, pp. 96-98).

† T. Barron and W. F. Hume. *Memoir on the Eastern Desert* (Central Portion), especially in Practical Notes, (pp. 255-257) and Appendix II, (pp. 295-296).


BALLAS
KOM BILAL
TUKH
R. NILE
QUS
NAQADA
or Qurn
SCALE
1 : 100,000

CHAPTER I.

Phosphate Deposits of Nile Valley.

Prior to the formation of the Geological Survey in the summer of 1896, the existence of phosphate-bearing beds of economic value in the Nile valley or Egypt generally was entirely unknown. Figari Bey in his description of the beds between Siloë and Edfu mentions an ash-grey sandy breccia with remains of bones, fish-scales, and shell fragments, but makes no statement as to their possible commercial value, and other writers on the geology of Egypt are silent on this subject.

It was only in the early part of 1897, while engaged in the examination and mapping of the district on the east bank of the Nile extending from a little to the south of Esna as far as Qena on the north, with the object of reporting on the extent and value of the "Tafla," a nitrate-bearing clay, that Barron discovered the existence of bone-beds, some of which looked exceedingly promising. The first of these was found in a small hill about 18·5 kilometres south of Esna, where three thin beds occurred :—

(Top) Oyster bed (with a layer of conglomerate in the middle containing bone fragments, 0·28 metre), total thickness 3·3 metres.

(2) Thin layer of fissile limestone with siliceous concretions.

(3) Bone-bed 0·125 metres.

(4) Hard limestone 0·8 metres.

(5) Bone-bed with fish teeth, etc., with layer of shells at base 0·28 metres (probably Figari Bey's bed).

Sandy shales underneath.

Samples of these were examined in the Khedivial Laboratory, but were found to be too poor in phosphoric acid to warrant their being worked. From this point northward, no other signs of phosphate-bearing beds were obtained until east of Qift, where during an examination of a small plateau mainly composed of shales similar to those worked for Tafla, a brownish bed about 1 metre thick, showing on its

fractured surface numerous fish vertebræ, teeth, and what are probably coprolites, was met with.

The southern extension of the phosphate-bearing deposits is at present unknown, but in journeying from Luxor to Aswan, the fact impresses itself that the Cretaceous beds must have a very wide extension between Esna and the great plain north of Daraw, the Eocene outliers disappearing and being replaced by a series of lower plateaux which both in position and character recall the strata under discussion. The station of Mahamid is the best point from which to start further examination, and should these beds prove phosphate-bearing, the supply of low-grade Egyptian phosphate would be very considerable.

Bone-bed to the East of Qift. (See Plate I.)

Outcrop.

This bed is found on the top of a plateau called Jebel El Qurn, which lies at the junction of Wadi Matula and Wadi El Qurn, whose combined drainage bears the name of either wadi, according as the guide is an Ababda or a Maazi.

From the plateau to the cultivation, a distance of 6 or 7 kilometres, there is a good road in the bed of the wadi, and afterwards across the cultivation to Qift station, a further distance of 3 kilometres, making the nearest point of the bone-bed in all 10 kilometres from the railway. From the furthest point of this plateau examined, the distance to Qift station is 20 or 21 kilometres. As there is no obstruction in the way, a light railway could be put down at a small cost, by which the phosphate could easily be brought down to the Nile.

Extent of the phosphate bed.

The plateau in which this bed occurs measures between 1 and 2 kilometres at its greatest width, and is 9 to 10 kilometres long. At first it is triangular, but finally runs off in a south-easterly direction in a tongue of somewhat rectangular shape. This plateau is undoubtedly continued further to the south, and in all probability exists behind that of the Eocene which lies on the east side of the valley, as patches of a phosphate bed were noticed in a traverse to the east of Esna, at which point, however, it was considerably more distant from the river, being at least 38 kilometres from the Nile. If the country to the east of the Eocene table-land were examined, it would possibly be found that the "Bone-bed" formed the top of a small subsidiary plateau at the foot of the limestone scarp, as in Wadi Hammama.

In the plateau of Jebel El Qurn, the phosphate bed is well-marked by beds which underlie and overlie it. Beneath it is a sandy limestone or calcareous sandstone, full of casts of *Arctica Barroisi* and *Trigonoarca multidentata*, while it is overlaid by a thin blue cherty limestone which forms large, flat, elliptical concretions. These two beds form never failing guides where the bone-bed happens to be obscured by rubble. Round the edges of the plateau, as well as where water-courses have begun to form, it has been removed by denudation. In the triangular patch previously mentioned, the surface is practically composed of the blue limestone more or less broken up, with the phosphate bed underneath. In some cases this bed forms the surface of the plateau, when it is in the form of rubble; while in others (and these are in a large majority) it is covered by rubbish which only in a few instances attains the thickness of 3·0 metres. As this is not in a hard, consolidated condition, its removal presents no difficulty. Where the phosphate is broken up, screening and hand-picking may be necessary, but that is only a small item. Between the triangular patch, and the rectangular piece to the east of it, the bone-bed has been denuded away; and in this latter area itself, it occurs only in the ridges between the water-courses. As it is followed back to the south-east, it covers more ground, where in places it forms the surface, and can be scooped up in fragments without difficulty.

The thickness of the normal bed is nearly 1 metre, but the upper part of it has already undergone silicification. Chemical examination has shown that this does not affect the sample very injuriously, for in a highly siliceous specimen analysed there was a difference of about 7 % phosphoric anhydride between it and a normal sample. Even in the places where silicification has been carried to the greatest extent, 0·23 of a metre of good unaltered bone-bed is found, while it rises to 0·3, 0·45 and 0·6 metres in other places, the most common thickness being 0·45 metres.

From what was seen, it appears that the siliceous character of this bed is variable, but tends to increase towards the west.

During the examination of this plateau, there were noticed beneath the main phosphate layer, several other bone-beds whose position detracts from their value, as the cost of extraction will be greater. From 3·2 to 3·6 metres below the main phosphate bed, there is a sandy limestone or calcareous sandstone which contains a good many scales

and bones of fishes. In the middle there is a layer of 0·07 metres of very good material, but throughout the entire thickness of 0·76 to 0·91 metres there is a considerable quantity of phosphatic material present.

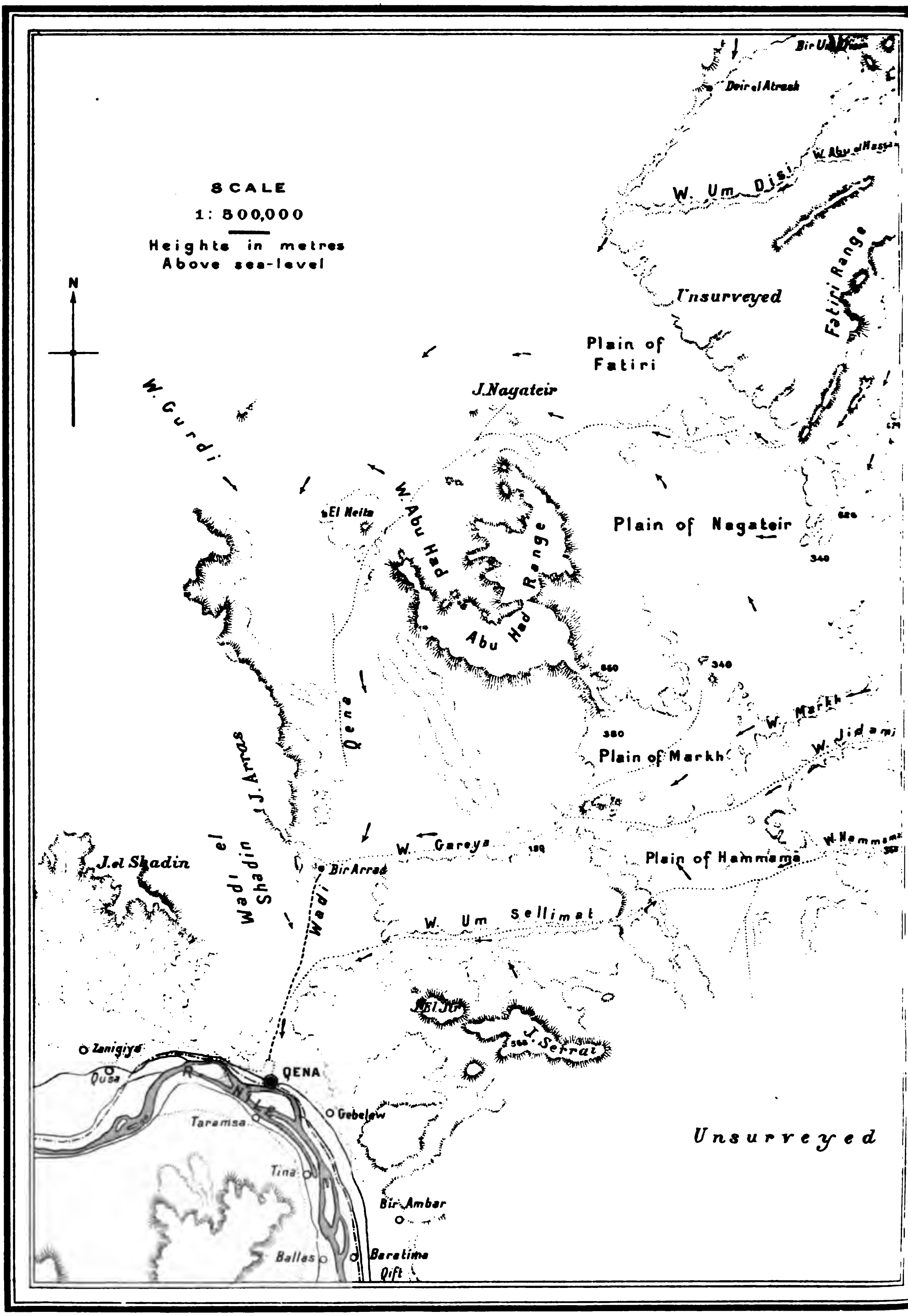
In a specimen from the normal "Bone-bed" examined in the Khedivial Laboratory, 22·5% of P_2O_5 (phosphoric anhydride) was obtained, which is equal to 49·11% of tricalcic phosphate.

Dr. Beam has since examined the locality, and the specimens collected by him have been analyzed in the Survey Department laboratory with the following results :—

P_2O_5	$Ca_3(PO_4)_2$
20·68	45·08
21·07	45·99
20·66	45·08
24·63	53·76
21·93	47·89

The percentages thus obtained indicate that an average of over 45% $Ca_3(PO_4)_2$ may be reasonably expected at this locality.

West Bank of Nile.—The bone-beds on the east side of the Nile valley in the neighbourhood of Esna, are in all probability repeated, at the same horizon, on the western side. Between Esna and Qena on the left bank of the cultivation, no bone-beds were found, the base of the Esna shales, below which the bone-bed series lies, not being exposed. To the south of Esna, where the Cretaceous must come to the surface, it is almost certain that the bone-beds will be found to occur, and they will not in all probability greatly differ from those on the eastern side. This area has, however, not yet been examined or mapped.



Phosphatic beds

CHAPTER II.

Phosphatic Beds in the Eastern Desert.

1. Near Qena.

As already stated, during a geological examination of the Nile Valley to the south of Qena in the spring of 1897, a phosphatic rock was recognized in the immediate neighbourhood of Qift, though owing to the faulted character of the ground, further generalization was at the time impossible. In the autumn of the same year, during an expedition to the old mines of Aradia, on the return journey from the igneous hills a road was taken which cut through a low plateau running from south-west to north-east, parallel to a ridge connecting the limestone ranges of Serrai and Abu-Had. An examination of the rock exposed in the gullies and slopes on the eastern edge of this plateau led to the re-discovery of the phosphate bed, and the simultaneous discovery of undoubted Cretaceous fossils in the overlying limestone, a key being thus provided which established that the phosphatic beds are in every instance intimately associated with strata of that age.

The exposure in question, which in a straight line is a little over 20 kilometres from Qena, is easily reached by the main camel road, which first ascending Wadi Qena then follows the large branch of Wadi Um Sellimat to its head. Up to this point the track is of the easiest, but after crossing the ridge, the path descends somewhat steeply though presenting no special difficulties even to loaded camels, and in its lower half passes through the Cretaceous beds (which form low cliffs on both sides), finally opening into the Hammama plain.

The plateau can also be reached by the still easier road, which after traversing Wadi Qena, enters Wadi Gareya, the latter, without the intervention of any pass, leading direct into the Hammama plain. Thus as far as roads and distance from an important centre are concerned, there are no insuperable difficulties to transport.

Turning now to the beds themselves, the typical succession and thickness are as follows :—

1. The summit of the plateau is formed by a hard, bluish, crystalline limestone, on whose weathered surfaces appear abundant specimens

of Cretaceous Cephalopoda (*Ptychoceras*, etc.), and other fossils, this passing below into a less fossiliferous limestone. Total thickness, 0·45 metres.

2. Below this limestone is a lighter and more siliceous variety, very compact and of nodular aspect, in its upper layers containing fine casts of *Ptychoceras*, and alternating with chert beds, 1·2 metres thick.

3. A bone-bed, or more strictly a coprolite bed, partly siliceous, which on fracturing shews a number of rounded white fragments, fish-teeth and vertebræ, (*Lamna*, *Corax*, etc.). This layer, about 60 centimetres thick, is separated from another 30-centimetre bed by a band of siliceous limestone 30 centimetres thick, while the lower bone-bed is separated by a green marl 15 centimetres thick from—

4. Oyster limestone, 1·2 metres thick.

It is therefore evident that the overburden to be dealt with is a hard limestone about 2 metres thick, the question being whether this can be wedged off, or whether the phosphate bed will have to be cut out from underneath, pillars being left. In the numerous faulted portions, the first method may be found possible, as the upper limestone is much cracked. Owing to the phosphate and oyster beds being softer than those overlying them, the latter overhang in many places. The best method of treating the overburden will probably have to be determined on the spot by experiment.

The proved area mapped by Green in which the Cretaceous beds are known to exist, extends over a length of 25 kilometres from the base of Jebel Serrai to the southern edge of Jebel Abu Had, with an average breadth of over a kilometre. It cannot, however, be absolutely said, that the whole 25 square kilometres are occupied by phosphate beds, because of the disturbance by faulting, but that within that space deposits of this nature are of frequent occurrence.

Though the Cretaceous plateau has been breached by Wadi Hammama where it joins Gareya, from this point it becomes more and more marked to the north, until at the foot of Jebel Abu Had it forms a vertical cliff over 40 metres high, capped by yellow outliers of more marly limestone. The summit of the plateau is determined by the *Ptychoceras* limestone, beneath which is a bone-bed, and over 30 metres of green shales, but in addition at its base is a second bone-bed, containing teeth of *Lamna*, etc.

The plateau itself, following the dip-slope of the beds (about 4° NW.) rapidly sinks into the El Nagateir plain to the northward, and although two traverses have been made to the north of this point, it has not again been struck, so that the southern end of Abu Had must be considered as the northern limit of the extension of the phosphate beds.

Probably as the result of faulting, fossil-bearing Cretaceous strata form the surface of a low broken plateau at the foot of the main cliff, the summit of these ridges being in several places crowded with the remains of poorly preserved *Baculites*. Immediately underlying this layer is a bone-bed containing oysters, teeth of *Lamna* and *Corax*, coprolites over 2½ centimetres in length, abundant vertebræ, and at the junction with the underlying marls, large bone fragments; most of the latter from a theoretical stand-point are unfortunately in a very brittle condition, though from the practical point of view this would be an advantage. The Abu Had lower plateaux, though further from Qena, therefore claim attention on account of the absence of a hard covering-layer, and the greater size of the remains to which their phosphatic character is due.

Summarizing the above remarks, so far as is known at present, phosphate beds form part of the Cretaceous series wherever examined on the eastern side of the Nile Valley, the latter extending from the southern end of Abu-Had, possibly as far as the Daraw plain, while the distance between them and the Nile Valley or railway gradually diminishes from over 20 kilometres to nothing. Faulting, too, as in the case of Wadi Matula near Qift, may expose these strata at points where otherwise they would not be expected in the normal succession.

Character of the Phosphates.

Hitherto the distribution of the phosphate-bearing deposits has alone been considered, but the question of composition is obviously of prime importance, and since the publication of the first edition of this report, further analyses have shown the percentage of tricalcic phosphate in the samples from Wadi Hammama to be 50·78, 29·38, 45·65, and 43·97 % respectively, or an average of over 42 %.

These analyses, together with those of the specimens from Wadi Matula and Jebel Duwi subsequently described, show that the probable average will be from 20 % to 25 % of phosphoric acid ($P_2 O_5$ really), or

in other words a rough average of from 40% to 50% of tricalcic phosphate. Any question of export would seem to be doubtful, as may be gathered from the following extract of a letter sent by Mr. J. C. Winkfield, of the firm of Pickford and Winkfield, a leading authority on the value of phosphates. "At the present time you are probably "aware that there is a very abundant supply of all classes of phosphate "of lime ranging from the low grade 40% Belgian up to high quality "Florida, testing as much as 78·80%; to-day the value of the highest "grade phosphate is about 6*d.* per unit per ton of phosphate of lime, "which after deducting freight, inland and other charges, does not "leave the miner more than about 12*s.* per ton net at the mines.

"Nothing is so disappointing and unsatisfactory as phosphate min- "ing, because as you are no doubt aware, the deposits are more or less "pockety, require very careful handling, and are in many cases costly "to work. In addition to this, the buyers insist upon very stringent "guarantees, both as regards the percentage of phosphate of lime, as "well as oxide of iron and alumina. In selling high class phosphate, a "minimum guarantee of 78% phosphate of lime, being the equivalent "of 35·75% phosphoric acid, and a maximum of 3% oxide of iron and "alumina has to be given, and when the quality falls below 78% or "above 3%, absolute rejection of the cargo is made. For your guidance, "I enclose copies of analyses of a good and bad cargo of Florida. "In the one case you will notice the phosphate of lime runs as high as "79·03% with 2·26% oxide of iron and alumina, in the other, only "75·16% phosphate with 5·43% iron and alumina. Such a quality as "this is absolutely unsaleable.

"Besides the above standard, a good low class phosphate of lime is "very easily disposed of containing from 56 to 63°/₀. Outside phos- "phate of lime, there is also a moderate demand for phosphate of alumina."

In the *Manufacturer's Record*, July 29, 1898, pp. 4-5, a large series of analyses are given, which will serve as terms of comparison. Some selected types are given below:—

	Hard Rock Florida.	Florida River Pebble.
Phosphoric Acid	36·73	27·91
Iron Oxide	·70	2·57
Alumina	1·63	—
Bone Phosphate	80·18	60·93

	High grade Algerian Phosphate.	Phosphate from Somme (France).
Moisture	3·00	2·00
Bone Phosphate	64·88	78·50
Phosphoric Acid..	29·76	35·70
Alumina	0·31	0·70
Oxide of Iron	0·24	1·40
Lime	50·68	—

	South Carolina Phosphate.	Belgian Phosphate.
Moisture..	0·5 to 4·0	0·25
Phosphoric Acid	26·0 „ 29·0	20·59
Iron Oxide	1·0 „ 3·0	18·64
Alumina	trace „ 2·0	—
Bone Phosphate	57·0 „ 63·0	45·30

Egyptian (Eastern Desert) phosphate 22·5% phosphoric acid, or 44 to 50·5% Bone Phosphate.

Comparing the above analyses, the Egyptian variety, so far as the samples have been examined, is somewhat inferior to the Carolina and superior to the Belgian. The question of export does not arise, seeing that Egypt as an almost exclusively agricultural country, could take any available supply. The point to note here is, that Egypt possesses an apparently unlimited supply of low grade phosphate within easy reach of the Nile Valley.

2. Phosphates in the Eastern Red Sea Hills.

On the road from Qena to Qosseir, a little south of the latter town, is the very conspicuous range of Duwi, owing its origin to faulting, which has let down limestones of Eocene and Cretaceous age against older rocks. While the main crest is formed of the Eocene limestone, it is flanked on the south by a lower plateau of Cretaceous limestone, which is separated from Wadi Abu Zeran by low hills of brown-red Nubian sandstone. It is interesting to find that in this series the bone-bed reappears, containing fragments of bone and vertebræ, coprolites and teeth of *Lamna*, etc., the whole bed, which is overlaid by thick limestones, being itself about 0·45 to 0·6 metres thick, and having undergone a certain amount of silicification. Although near a small sea-port, its position is otherwise not very favourable from an economic standpoint, though of theoretical interest. Similarly, at the western end of the Duwi range, in Wadi Saga, the Cretaceous beds rise from underneath the Tertiaries at a point where it suddenly narrows from a wide plain to a ravine; they consist mainly of bone-beds and cherty

layers, closely associated and alternating, and of greater thickness than had previously been observed. In the Saga plain itself are two ridges, curving round in a semi-circle, the one towards the Duwi range consisting of the bone-beds dipping at an angle of 20°.

Confluence of Wadi Wasif and Wadi Safaja.—Phosphate-bearing beds also occur on the eastern slope of the Red Sea hills, in a faulted syncline at the confluence of the Wadis Wasif and Safaja, 11 kilometres from the sea. Here the exposure is limited, being 50 to 100 metres wide, and having an extension of about 7 kilometres. There is a good road down Wadi Safaja to the sea, where there are 13 fathoms of water close to the shore.

In many places the phosphate bed is not well exposed, being covered with talus, but the following section measured in a watercourse gives a good idea of the beds there, the base of the section being the bone-bed:—

(Top.) (1)	Baculite limestone, etc...	1·0 metre thick
(2)	Marly limestone and marls	7·7 „ „
(3)	Bone-bed No. 1, similar to No. 2	2·5 „ „
(4)	Blue siliceous limestone, probably the same as that overlying the phosphate bed in Jebel El-Qurn..	0·3 „ „
(5)	Flinty bed containing silicified coprolites..	1·0 „ „
(6)	Bone-bed No. 2, containing fish-teeth, spines, and coprolites..	1·0 „ „

The overlying beds were obscured by debris, but presented a marly character.

This section shows, that although the phosphate beds are here much thicker, their value is considerably lessened by the great thickness of "overburden" which would require removal before they could be worked. Their position, too, is against them, as the cost of transport by sea and land would be a very large item.

3. Phosphates in Eastern Desert north of lat. 27° N.

Bone-beds are not only present in the Cretaceous series south of lat. 27° north, but also to the north of this line, a specimen from the Campanian series near Bir Mellaha yielding 40·12% tricalcic phosphate. The limestone range running parallel to Jebel Esh north of that locality also contained bone fragments and phosphatic layers, though these have not been studied in detail.

CHAPTER III.

The Phosphatic Beds of the Western Oases.

1. Dakhla Oasis.

The existence of thick bone-beds in the lower part of the great Cretaceous escarpment to the north of Dakhla Oasis, was first noticed in February, 1898, and during the geological survey of this area in the following months, the exact extent and development of these beds was mapped and examined.

Prof. Zittel, who geologically examined this oasis in 1874, during the progress of the Rohlfs Expedition, mentions brecciated beds containing fish teeth, as occurring in the lower strata of the Cretaceous series. These doubtless are identical with the bone-beds now to be described, which probably were poorly developed at the points examined by Zittel, as they do not seem to have been recognized by him as true bone-beds, or as of any economic importance.

The phosphatic deposits occur throughout the oasis, extending from the extreme west at Qasr Dakhla to the extreme east at Tenida, a distance of over 50 kilometres. They, and the strata which occur in association with them, occupy the entire area between the main cliff, or wall, of the oasis and the northern limit of the cultivation on the low ground, a breadth varying from 3 to 6 kilometres. The total area of outcrop is thus roughly something like 200 or 250 square kilometres. The bone-beds, together with their associated clays and sandstones, form in fact a low subsidiary plateau between the main cliff and the cultivated lands, the surface of which has a well marked dip slope of 2° or 3° to the north. The escarpment of this plateau, facing the low cultivated ground, is very irregular and frequently cut up into numerous indentations separated by promontories, so that its distance from the cultivated lands and villages varies considerably; whereas in the districts of Qasr Dakhla, Birbaya, Budkhulu, Rashida, Hindaw and Smint this escarpment is usually contiguous to the cultivation, between Smint and Belat, and beyond the latter to the west, it recedes and keeps much nearer to the main cliff; at Tenida it is however quite close, in places actually abutting on the cultivated land. Outcrop.

The bone-beds, with the exception of a small patch, are not found in the desert to the south of the cultivation.

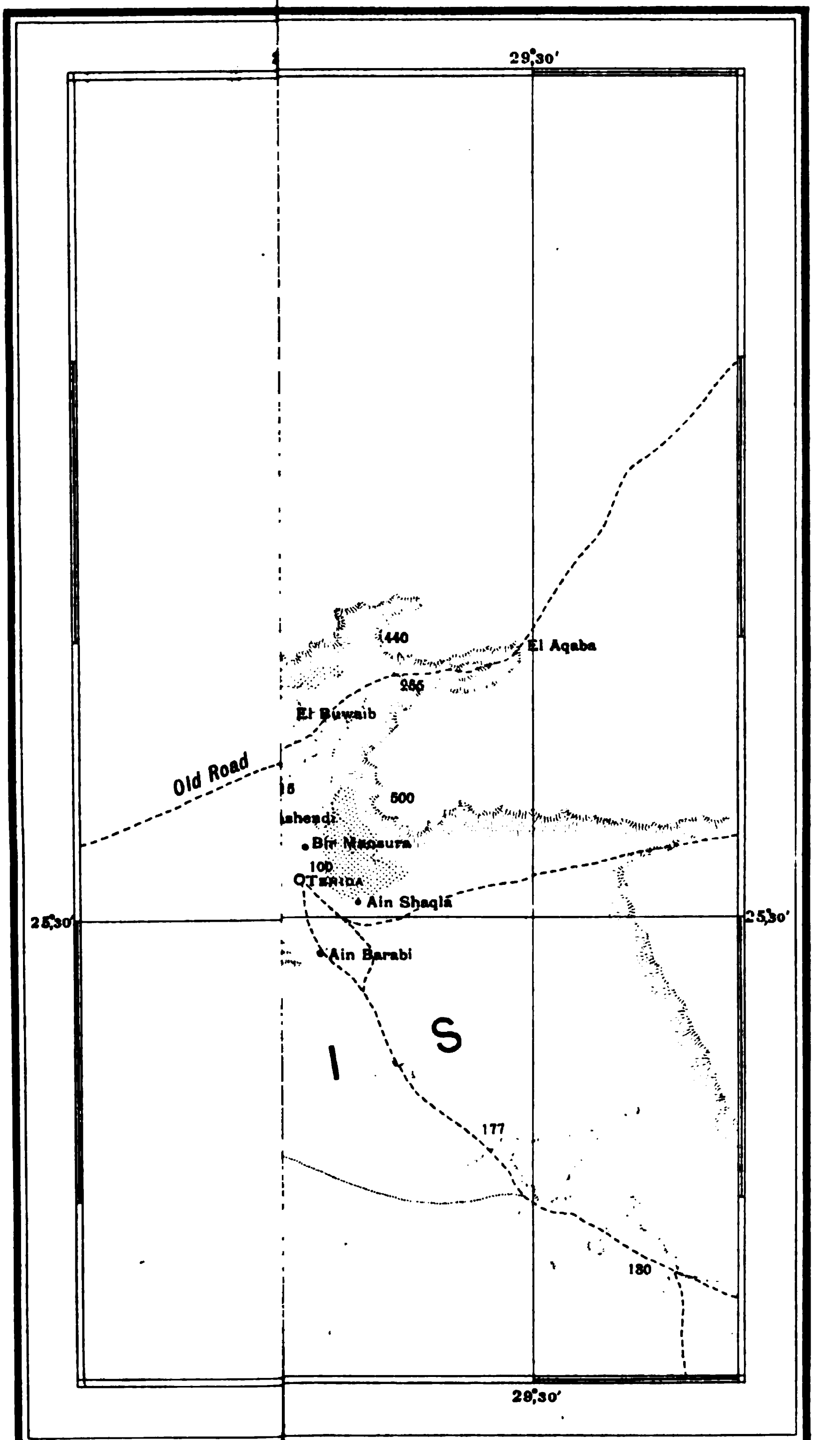
The extension of these beds to the east and west of Dakhla is not known with any certainty. To the west, however, if they do not altogether die out, they become of much less importance. Between Dakhla and Kharga they occur in all probability to some extent, although their outcrop has not been followed; the latter, if the beds are developed, would be found near the base of the prominent cliff which runs between the two oases. No trace of these beds was seen on the Derb El Gubari, the lower road from Dakhla to Kharga, which is at a considerable distance from the above-mentioned cliff.

Thickness, etc. From the detailed sections published in the "*Report on the Geology of Dakhla Oasis*," (1) it will be seen that there are usually several distinct bands, separated by intervening beds of clay, sandstone, etc. The following is a typical section of the escarpment, and was measured one kilometre south-east of Rashida.

Top of Escarpment.

	Thickness in metres.
1. Hard brown, more or less crystalline, limestone passing in places into white chalk..	0·65
2. Blue laminated clays	2·50
3. Brown, rather friable, coprolitic fish-bone bed..	0·65
4. Grey marly shales, and brown sandy clays	3·00
5. Light brown coprolitic phosphatic bed (Sample O)..	0·30
6. White phosphatic bed (5 cent.) with hard white shaly clay	0·30
7. Brown sandy clays..	2·00
8. Very coarse, brown coprolitic fish-bone beds, with numerous teeth (Sample N)..	0·65
9. Clays, sandy clays and sandstones	6·50
10. Hard white phosphatic bed (Sample M)	0·25
11. Slaty blue laminated clays, with a few white bands.	4·50
12. Brown, coarse, sandy, gritty bed, with a certain quantity of fish remains..	0·65
13. Hard brown sandy limestone with casts of shells	0·65
14. Dark green sandy clays, slaty blue laminated clays, with thin veins and beds of gypsum.	7·50
15. Alternating light green clays and brown sandstone. Thin veins of gypsum, opaque white and dehydrated on surface. Black carbonaceous matter and obscure plant remains are seen in some of the sandy beds. Beds of hard dark silicified, concretionary weathering sandstone occur near base	15·00
16. Red clay, often marly, and green (½ metre) at top..	7·50
Base at Cultivation Level.	52·60

(1) H. J. L. Beadnell. Dakhla Oasis: Its Topography and Geology. See especially Chapter VII, pp. 96-98.


29°30′
El Aqaba
1440
255
El Buwaib
Old Road
500
Bir Mansura
100
Tenida
Ain Shaqla
25°30′
25°30′
Ain Barabi
I S
177
180
29°30′

At this point the phosphatic bands therefore form five different layers, with a total thickness of about 2½ metres. The following table shews the approximate total thickness of bone-bed at the several places where sections have been measured :—

Qasr Dakhla	3	metres.
¾ kilometre NE. of Birbaya	1	„
At village of Birbaya	2·5	„
2 kilometres E. of Rashida	1·2	„
1 kilometre SE. of Rashida	2·5	„
Ain El Sabil, 3 kilometres NNE. of Hindaw	2·5	„
Tenida	2	„

The average thickness of bone-bed is therefore usually between two and three metres. The different bands do not remain constant over large areas, but vary from point to point in thickness, distance from each other, etc.; but the beds taken as a whole are fairly constant in character. The colour is usually dark brown, but a notable exception is formed by the less frequently occurring compact white bands. The rock varies a good deal in compactness, at times being very hard compact and difficult to break, or again becoming soft and friable. The beds are almost entirely composed of fish remains, chief among which appear to be coprolites, together with broken up bones, including occasional vertebræ and numerous fish teeth of the genera *Lamna*, *Otodus*, etc. Probably coprolites form the bulk of the mass.

Exploitation.

Throughout the desert margin bordering the cultivated lands of Qasr Dakhla, Birbaya, Rashida and Hindaw, these beds could be worked with great facility. At Smint also the outcrop is at no great distance from the village. Little could be done between Smint and Belat or at the latter place, but at Tenida a fair extent occurs in close proximity to the village.

At the first four villages named the supply would be very considerable even if the beds were only worked along their outcrops on the escarpment. Later on, when further developed, the overburden to be removed would not exceed a metre or two, and the output obtainable is practically unlimited. But probably the supply would suffice for a considerable time if the bone-beds were simply worked where they are exposed along the cliff face, without removing any overlying material.

Analysis. Thirteen samples from different localities were selected for analysis and the results obtained for six of these are shown in the table below; the remainder have not yet been examined, but in all probability would not vary in any great degree from those now given.

The six specimens analysed represent very fairly the variation in quality of the different bands, as they were selected from what appeared in hand specimens to be the different varieties present.

In all probability by working only the highest grade bands the percentage of tricalcium phosphate could very easily be kept up to between 55 and 60 per cent. If all the bands were worked indiscriminately the average would probably be from 40 to 50 per cent. In each locality there is as a rule at least one good bed, which is usually also the thickest; the thinner bands, which point to less favourable conditions for the development and multiplication of the fish which swarmed at the time of the deposition of these strata, are usually the poorest in quality, in percentage of phosphoric anhydride, and in freedom from enclosed sand and clay.

The analyses shew that the richest bands are almost equal to the best Carolina phosphates, and do not compare unfavourably even with the fine Florida deposits.

Transport, etc. It is clear therefore that the material occurs in sufficient quantity, and has a sufficiently high percentage of phosphoric anhydride, to render it of the greatest economic value, especially to an agricultural country. It occurs moreover in such a position as to render its exploitation extremely easy. The only consideration therefore is the important one of transport.

If worked solely for the use of the oasis itself, there is no question of transport at all, the material being on the spot. It is probable that great benefit would result to the land from the use of a phosphatic fertilizer, as the soil is becoming poorer every year; the only manure it receives being a very small amount of various salts, of doubtful fertilizing value, deposited from the water of the springs used in irrigation, and probably also a certain amount of phosphatic dust, derived from the denudation of the exposed bone-beds along the escarpment, blown and deposited by the north winds on the cultivated lands. The amount of phosphatic material thus received is unknown, but it is quite possible that this is the cause of the fine quality of some of the soil of Qasr Dakhla, Rashida, etc.

Whether it would pay to erect plant in Dakhla for crushing, washing, drying, and converting to superphosphate is doubtful, but this would not probably in any case be undertaken at the outset. Inexpensive grinding mills of some sort, either worked by hand or wind power, could however easily be provided.

Transport to Nile Vallery.

As at some future time, when the value of these beds is more fully appreciated, the question of the transport of the material, either in its native state or after conversion into superphosphate, to the Nile Valley may be raised, it will be well to say a word or two as to the intervening country. From Dakhla to Kharga the desert is fairly level and the construction of a light railway would not present any very great difficulties. The distance to be traversed without water would be about 135 kilometres.

Water is plentiful in Kharga. Between Kharga and the Nile Valley, near Erment, lies a high plateau, which itself would present no difficulties to the construction of a light railway, except that no water is available. The ascent from Kharga to this plateau, a height of some 300 or 400 metres, would necessitate the construction of an inclined plane system of some magnitude. The descent of the cliffs to the Nile Valley would be one of comparative ease.

The only other transport available is by camel, which is largely used for the export of dates, the journey from Dakhla to the Nile Valley taking from 7 to 8 days.

Analysis of Dakhla Bone-beds.

SAMPLES	LOCALITY	Phosphoric Anhydride (P_2O_5)	Tricalcium Phosphate ($Ca_3(PO_4)_2$)	DESCRIPTION OF BEDS
		%	%	
E	Qasr Dakhla	27·93	60·97	Coarse brown coprolitic bone-bed.
N	Rashida ..	25·88	56·50	Very coarse brown gritty phosphatic bed, full of bones, teeth, and coprolites.
G	Birbaya.. ..	21·43	46·78	White gritty phosphatic bed.
Q	Hindaw.. ..	20·89	45·60	Hard brown compact coarse brecciated bone-bed.
M	Rashida ..	16·21	35·37	Hard white phosphatic bed.
H	Birbaya.. ..	12·29	26·82	White calcareous phosphatic bed.

2. Baharia Oasis.

Other localities on W. side of Nile.

In this oasis the Cretaceous bone-beds are represented by a single thin band, found at various points both in the hills within the depression and on the western escarpment. This band is highly siliceous and the rock very hard and compact. From its siliceous character and slight development, this bed may be regarded as of little or no economic importance. The following is the analysis :—

Phosphoric Anhydride	11·49%
Equivalent to	
Tricalcium Phosphate	25·09%

CHAPTER IV.

Algerian and Tunisian Phosphates.

It may be of interest to consider the history and character of the Algerian and Tunisian phosphates, which have had so remarkable a development during the last thirty years. (For an excellent summary of the literature, &c., of these deposits see Prof. de Launay, *Les Richesses Minérales de l'Afrique*, Paris, 1903, pp. 206-236), on whose work some of the following notes are based.

They owe their discovery to the formation of a Geological Survey in Algeria, M. Thomas in 1873 calling attention to the presence of a rich deposit of phosphate of lime in the Suessonian strata of that province. From 1883 to 1887 this geologist, together with M. Aubert, recognized the presence of phosphatic beds of the same age in the south of Tunis and the region of Gafsa. Only twenty years later, viz. 1894, the phosphates commenced to be worked in earnest, with remarkable results, the production in Algeria during 1900 being 319,422 tons, officially valued at 20 francs a ton, and in Tunis it was estimated that 260,000 tons would be obtained in 1902, a grand total of over 575,000 tons.

With regard to the age of these beds, it may be stated generally that the rich phosphates are present in the lowest beds of the Eocene series, viz. the lower Suessonian, though the results obtained by M. Pervinquière tend to show that the productive strata at Gafsa are somewhat younger, viz. Middle Eocene.

The Algerian phosphates are of two types : 1. The marls with nodules, worked for example at Souk-Arrhas, which have never yielded good results, and the brown phosphatic limestones, such as are obtained at Tibessa and at Gafsa, these latter alternating with the marls above mentioned. The quality most sought after breaks easily in the fingers and has a specific gravity of less than 2. It is formed by the agglomeration of a number of fine brown and green grains, the former consisting of phosphate of lime, and the latter closely resembling the green mineral glauconite. With them are associated fragments of quartz and organic remains. With regard to the percentage of tricalcic phos-

phate some of the Algerian deposits are very rich; those worked in the great plateau of Djebel Dyr have from 60 to 70 % $Ca_3 (PO_4)_2$ in the richest parts, but at the same time the strata show rapid variations in comparatively short distances. One rich area in the plateau some 200 metres long yielded about 300,000 tons, but to the north it drops to an average of barely 50 %, though in places there are rich pockets. It is to be regretted that hitherto no Egyptian deposits have been found which can compare with these Algerian beds in high percentage of phosphates. In brief, it may be stated:

(1) The Egyptian phosphates like those of Algeria are widely distributed.

(2) They differ in age, the phosphate-bearing strata being older in Egypt (Upper Cretaceous) than in Algeria (Lower Eocene).

(3) The richest Algerian have 10-20 % more tricalcic phosphate than the richest Egyptian samples.

(4) The Egyptian deposits seem to be more constant in extension than the phosphatic beds in Algeria.

CHAPTER V.

Chemical Report on the Phosphates.

During the course of the recent Geological Survey of Egypt extensive phosphate deposits have been discovered; some of these are situated in the north in the peninsula of Sinai, some in the south in the oasis of Dakhla, while others lie between the two, being found in Baharia and also in the eastern desert in two localities, near Qena and in the Red Sea Hills respectively.

These phosphate beds, which range in colour from a light grey to a yellowish brown, are composed for the most part of fossil bones, such as the vertebræ and teeth of fishes, together with coprolites and varying quantities of siliceous matter, carbonate of lime, and iron and aluminium compounds.

At present the whole of the samples taken have not yet been examined, but those already analysed give the following results :—

TABLE I.

No.	PLACE OF ORIGIN.	Phosphoric Acid (P_2O_5) %	Tricalcium Phosphate ($Ca_3(PO_4)_2$) %
4410	Sinai	5·93	12·94
4200	„	22·19	48·44
..	„	24·63	53·77
1505	Baharia	11·49	25·09
4269	Dakhla	27·95	60·97
4272	„	21·43	46·78
4273	„	12·29	26·82
4274	„	20·89	45·60
4277	„	25·88	56·80
4278	„	16·21	35·37
..	Near Qift..	20·68	45·08
..	„ „	21·07	45·99
..	„ „	20·66	45·08
..	„ „	24·63	53·76
..	Wadi Matula	21·93	47·89
883	Near Qena	21·96	47·94
1744	Abu Had..	5·36	11·70
1860	Um Tagher	23·32	50·91
1861	Bir Mellaha	18·38	40·12
1711	Wadi Hammama	23·26	50·78
1765	„ „	20·15	43·97
1715	„ „	20·91	45·63
1981	„ „	13·46	29·38
6018	Gebel Qurn	16·54	36·10
1878	Gebel Duwi	20·66	45·10
1942	„ „	23·10	50·43

*

It will be seen that the samples are not all of equal value, the percentage of tricalcium phosphate varying from 11·70 to 60·97.

Before comparing these Egyptian phosphates with phosphates from other sources, it will be well to consider first the elementary question of the need of phosphates at all in agriculture.

The element phosphorus in the form of one or other of its compounds is most widespread in nature, and is essential to the building up of all animal and vegetable bodies. It is the characteristic ingredient of seeds, and forms nearly 50 per cent. of the mineral matter of the grains of the different cereals, besides occurring in all fruits and vegetables. The following tabular statement will make this clear :—

TABLE II. (1)

PLANT (ASH OF).	PHOSPHORIC ACID. (P_2O_5)
	%
Wheat Grain	48·5
Barley Grain	33·1
Maize Grain	44·8
Cotton Seed	31·1
Cotton Wood	8·1
Cotton Fibre	8·3
Berseem	5·3
Lucerne	6·0
Sugar Cane	4·8
Beans	34·6
Potatoes	17·6

Since plants derive the greater part of their nourishment from the soil in which they live, it follows that phosphoric acid is essential to a fruitful soil, in fact in a soil destitute of phosphorus no plant could grow however well supplied it might be with other food substances.

The amount usually present is however only small, a moderately fertile soil containing about 0·3 per cent, and, since all crops remove phosphoric acid to a greater or lesser extent, the supply must be renewed from time to time or the soil will become exhausted.

In nature the phosphorus taken from the soil is returned to it when the plants decay and the animals die, but in agriculture the vegetable

(1) *Manures in Egypt and Soil Exhaustion*, MACKENZIE and FOADEN, Cairo, 1896.

and animal produce are consumed off the land, and hence to retain its fertility we have recourse to manuring.

Manures are essentially of two kinds, natural and artificial.

Natural, or farmyard manure, can never by itself be sufficient to restore to the land the phosphorus removed by the crops, since it only contains this element in small quantities. According to analyses made by the late Dr. A.Vœlcker, F. R. S., farmyard manures contain from 65 to 80 per cent. of water and from 5 to 8 per cent. of ash, and of this ash only 0·3 to 0·5 per cent. is phosphoric acid.

Hence artificial manures containing phosphorus must be used.

This fact has long been recognized in Europe where immense quantities of special phosphatic manures are annually placed on the land.

In Egypt the same conditions exist as in Europe. The soil is very similar in composition and contains on an average 0·28 per cent. of phosphoric acid *, and the crops, as will be seen from Table II, all require considerable amounts of phosphorus. Hence in Egypt as in Europe the supply of phosphoric acid must be constantly renewed if the soil is to be kept fertile.

Since in Europe farmyard manure is never by itself sufficient to restore to the land the phosphorus withdrawn from it by the crops, it follows that in Egypt this is still more the case because the proportion of such manure available is very much less owing to a large part of it being used for fuel and the ashes wasted.

In Egypt however two sources of phosphoric acid are available that do not exist elsewhere namely Sebakh Qufri and the Nile mud.

The former contains on an average 0·72 per cent. of phosphoric acid *; while the latter contains about 0·25 per cent.

Concerning the phosphoric acid content of Nile mud there seems some difference of opinion.

In the two samples mentioned by Horner and analysed in London under the superintendence of Dr. Hofmann, there was no phosphoric acid †; Mackenzie and Foaden * give 0·32 per cent. and Parodi gives 0·24 per cent ‡.

In any case however neither Sebakh Qufri nor Nile mud contain sufficient phosphoric acid to balance the great and increasing quantity

* *Manures in Egypt and Soil Exhaustion*, MACKENZIE and FOADEN, Cairo, 1896.

† *Philosophical Transactions*, Royal Society, London, 1855.

‡ *Les Engrais en Egypte*, H. PARODI, Le Caire 1899.

annually removed from the land, the three-quarters per cent. in the former and the one quarter per cent. in the latter becoming the merest traces when calculated as a percentage of the soil over which the sebakh or the mud is spread. Hence artificial phosphatic manures are also needed in Egypt.

The utilization of crystalline and fossil phosphate by treatment with sulphuric acid was the work of Lawes and was patented by him in 1842: it was however merely the outcome of Liebig's suggestion in 1840 to render bones soluble in a similar way. This reaction of sulphuric acid upon tricalcium phosphate is, in its simplest form, as follows :—

$$\underset{\text{Ca}_3(\text{PO}_4)_2}{\text{Tricalcium Phosphate}} + \underset{2\,\text{H}_2\text{SO}_4}{\text{Sulphuric Acid}} + \underset{4\,\text{H}_2\text{O}}{\text{Water}} = \underset{\text{Ca H}_4\,(\text{PO}_4)_2}{\text{Monocalcium Phosphate}} + \underset{2\,\text{Ca SO}_4}{\text{Gypsum}} + \underset{3\,\text{H}_2\text{O}}{\text{Water}}$$

That is, tricalcium phosphate, which is insoluble in water, under the influence of sulphuric acid becomes monocalcium phosphate, which is soluble.

Not only however is the tricalcium phosphate acted upon by the sulphuric acid, but most of the other substances that are present, such as carbonate of lime, iron and aluminium compounds, etc., are acted upon at the same time. Hence the greater the percentage of foreign matter in the phosphate the greater must be the amount of sulphuric acid used, and the greater the cost of manufacture.

Thus although the total amount of phosphate present in a phosphatic mineral determines in a large measure its value, this value is also to some extent conditioned by the manner in which the phosphoric acid is combined, minerals rich in phosphoric acid combined with iron and aluminium being practically useless to the manufacturer of superphosphate. This is because iron and aluminium phosphates, being only soluble in the presence of much free acid, remain unacted upon and insoluble. Also, if the iron and aluminium be present as oxides, the case is much the same, since no sooner is the sulphuric acid added than these oxides combine with a portion of the phosphoric acid which would otherwise become soluble and retain it in the form of insoluble phosphates.

If, however, the iron is in the form of pyrites or silicate it has probably little or no action and is comparatively harmless.

Sand is the most innocent of all the useless ingredients in a mineral phosphate; it consumes no acid, it does not reduce the soluble phosphate, it is simply inert.

A small amount of carbonate of lime is useful, since, although it uses up sulphuric acid, the evolution of carbon dioxide that necessarily takes place insures a light porous texture in the manure, and the extra quantity of gypsum formed increases the dryness of the product.

Since the proportion of iron and aluminium compounds present in mineral phosphates has such a special bearing upon their commercial value these ingredients have been determined in some of the samples and the results are given in the following table :—

TABLE III.

No.	IRON AND ALUMINIUM OXIDES. ($Fe_2O_3 + Al_2O_3$)
	%
4272	1.20
4273	4·48
883	6·80
1860	14·96
1861	0·96
1711	1·68
1765	1·04
1715	8·64
1981	1·44
6018	10·72
1878	2·16
1942	1·76

It will be seen that although in some samples there are considerable proportions of iron and alumina other specimens only contain a very small amount, and if the phosphoric acid content in these latter were high enough they would be well adapted for making superphosphate.

A comparison may now be made between the recently discovered native phosphates and those used in Europe for the manufacture of superphosphate.

The mineral phosphates used for this purpose range from the ordinary grade Belgian containing 18·9 per cent. of phosphoric acid (equal to 41·3 per cent. tricalcium phosphate) to the good class West Indian which contains 40·2 per cent. of phosphoric acid (equal to 87·8 per cent. tricalcium phosphate).*

About 40 per cent. tricalcium phosphate is therefore the lowest limit for the successful manufacture of superphosphate, and this only produces a second rate article, the first qualities being made from phosphates containing from 60 to 80 per cent. of tricalcium phosphate.

Thus it will be seen that the quality of the Egyptian phosphates, even when containing only a small proportion of iron and aluminium compounds is not on the whole sufficiently good to warrant the idea that any successful manufactory of superphosphates could be established in Egypt, unless some of the other samples are much richer than those analysed, nor is it probable that any market could be found in Europe to which it would pay to export them.

The conversion of these native phosphates into superphosphate being them probably out of the question, there still remains to be considered whether it is possible to utilize them in their natural state, and whether mineral phosphates in their raw condition are of any value as manure.

It is manifest that all plant food before it can be assimilated must be brought into such a condition that it can readily pass by absorption into the root hairs, that is, it must be rendered soluble.

Since tricalcium phosphate is insoluble in water it would appear at first sight to be quite useless as a plant food.

Any such hasty conclusion however would be erroneous, for most forms of water-insoluble phosphate (certain crystalline mineral phosphates excepted) are largely soluble in weak acid solutions, and the acid sap of the root hairs as well as the carbonic acid and the humic acid in the soil act upon insoluble phosphate and render it soluble and available for plant life.

This being the case it will naturally be asked wherein then lies the superiority of superphosphate and what is the necessity for going to

* *Dictionary of Applied Chemistry.* Vol. II, T. E. THORPE, F.R.S.

the expense and trouble of rendering the insoluble form soluble when this conversion will take place in the soil?

Superphosphates however give quicker if not better results, though this is not, as is so often stated, because they are at once absorbed by the crops.

It is true that when placed on the land the superphosphate is soluble and in a condition to be immediately absorbed, but no sooner does it come in contact with the carbonate of lime and the oxides of iron and aluminium in the soil than part at any rate is once more rendered insoluble, though not in the hard dense form in which it previously existed but in a new form more readily acted upon by acid solutions.

Herein then consists the superiority of superphosphate, namely that a portion can be at once absorbed by the plants and that the rest, though actually it becomes insoluble, yet is in a form easily acted upon and again rendered soluble, and further that before any part is converted into the insoluble form there is time for it all to be diffused throughout the soil in a manner impossible to effect by merely mixing in.

To acknowledge the general superiority of soluble phosphates is not to confess that the insoluble form is useless, for such is not the case. The majority of mineral phosphates are very effective as manure when used in their natural state, provided they are finely ground, but this effectiveness varies on different soils. The soils most suitable for such manures are those rich in humus and poor in carbonate of lime, these being the conditions (presence of humic and free carbonic acid) most favourable to the solution of tricalcium phosphate.

Many methods have been proposed from time to time to discriminate between the total amount of plant food in a soil and that which can be immediately utilized by the crop.

The most satisfactory of these methods was proposed by Dyer* and consists in treating the soil with a 1 % solution of citric acid, the solvent action of which closely resembles the solution that takes place naturally in the soil by means of the carbon dioxide of the soil water and the acid juices of the plant roots.

In order to show that mineral phosphates if finely ground are of

* *Journal, Chemical Society*, 1894. Trans: p. 115.

real value as a plant food some samples of the Egyptian phosphates ground until they entirely passed through a sieve of 60 meshes to the linear inch, were digested in a 1 % solution of citric acid for seven days and the phosphoric acid that had passed into solution was then determined. The results are shown below.

TABLE IV.

NUMBER.	SOLUBLE IN 1 % CITRIC ACID.		
	Phosphoric Acid. (P_2O_5)	Tricalcium Phosphate. ($Ca_3(PO_4)_2$)	Proportion of the total Tricalcium Phosphate dissolved.
	%	%	%
4272	4·95	10·81	23·10
4273	4·56	9·96	37·13
883	0·92	2·01	4·19
1860	0·61	1·33	2·61
1861	3·43	7·49	18·66
1711	2·73	5·96	11·73
1765	1·70	3·71	8·43
1715	0·59	1·29	2·82
1981	3·25	7·09	24·13
6018	2·29	5·00	13·84
1878	0·22	0·48	1·06
1942	4·08	9·00	17·84

The calcium carbonate contained in the various specimens was not determined quantitatively, but it was noticed during the progress of the analysis that those samples which evolved the most carbon dioxide during the extraction with citric acid, and which therefore contained the largest amounts of calcium carbonate gave the smallest yield of phosphoric acid, the proportion of citric acid available for the solution of the phosphate being diminished in these cases by the amount used up in attacking the carbonate.

The percentage of the total tricalcium phosphate soluble in the 1% citric acid solution is sufficiently high in the greater number of the samples to prove that the Egyptian phosphates if simply applied to the land in a finely ground state will be of considerable manurial value.

The native phosphates will be useful to all classes of Egyptian agriculturists. They will be useful to the Fellahin and small farmers

who know nothing of superphosphates, nor would be able to pay for them if they did, for to these classes the choice is not between an imported soluble phosphate and a native insoluble phosphate, but between this latter or none at all.

They will be useful also to those who do know and can appreciate the difference between a soluble and an insoluble phosphate, but whose conditions of work are such as to make the cost of imported manures prohibitive, and for whom it is no longer a question as to which of the two gives better results, but whether it is not wiser to use what lies at their feet rather than to allow their land to become impoverished.

And to the large landowners the native product will be of value in supplementing the imported and high priced article.

SUMMARY.

From the above remarks it will be seen :—

(1) The phosphatic beds in Egypt have a very wide extension, having been obtained in the Western Oases, Nile Valley, Eastern Desert, and Sinai.

(2) They are always present at the same geological horizon, viz. the Campanian division of the Upper Cretaceous, and conversely, wherever this horizon occurs, phosphates may be expected.

(3) They contain an average of 40 to 50% tricalcic phosphate.

(4) With the exception of those found in Sinai and Dakhla they are easy of access and fairly close to the river and railway.

(5) By means of the very inexpensive operation of simple grinding, they can be prepared for use.

(6) They constitute a really valuable and cheap manure of a kind that is much needed, though the percentage of phosphoric acid is too low for export.

(7) No other phosphatic manure of similar value exists in the country, and the price of imported phosphate manures is such as to render them in many cases prohibitive.

LIST OF MAPS AND PLANS

Published by the Survey Department, and on sale at the Offices of the Survey Department, Giza, and the Geological Museum, Cairo.

Cadastral Maps.

	Price per sheet. Ordinary paper.	Price per sheet. Mounted cloth.
	Mill.	Mill.
Cadastral maps of all villages of the following Provinces are printed in Arabic only, showing number of Hods and Plots corresponding with the Individual holdings, as entered in the Mudiria Land Registers :		
Menufia Mudiria scale $\frac{1}{4000}$ and $\frac{1}{2500}$	50	65
Gharbia " " $\frac{1}{4000}$	50	65
Qaliubia " " $\frac{1}{2500}$	50	65
Daqahlia " " $\frac{1}{2500}$	50	65
Giza Mudiria scale $\frac{1}{4000}$	50	65
Fayûm " " $\frac{1}{2500}$	50	65
Qena " " $\frac{1}{2500}$	50	65
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Topographical Maps.

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Topographical Maps of the following Provinces, showing villages and Markaz boundaries and all water courses, published on scale $\frac{1}{10000}$.		
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	Ordinary paper.	Mounted cloth.
Maps of provinces of Lower and Upper Egypt, printed in English or Arabic separately, scale $\frac{1}{100000}$ of 4 and 2 sheets	120	—
Girga Province (Provisional) scale $\frac{1}{25000}$ published in English and Arabic in 18 sheets..	100	—
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Maps of Egypt.

	Sheets	Scale	Ordinary paper.	Mounted cloth.
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The First Cataract, in English (revised)	6	" $\frac{1}{10000}$	100	—
Kharga Oasis, in English	1	" $\frac{1}{50000}$	100	—
Dakhla Oasis, in English	1	" $\frac{1}{50000}$	100	—
Mersa Matru and Ras Allam Rum.	2	" $\frac{1}{25000}$	100	—
Lower Egypt and the Fayûm, 1901.	1	" $\frac{1}{500000}$	100	—

Town Maps.

	Sheets	Scale	Ordinary paper.	Mounted cloth.
Cairo and Environs, in English	4 sheets,	scale $\frac{1}{10000}$	120	—
" "	16	" $\frac{1}{4000}$	120	—
Mit-Ghamr, in English and Arabic	4	" $\frac{1}{1000}$	100	—
Mansura, " "	12	" $\frac{1}{1000}$	100	—
Suez, " "	20	" $\frac{1}{1000}$	100	—
Shebin-el-Kom, French and Arabic	2	" $\frac{1}{2000}$	120	—
Damanhur, " "	4	" $\frac{1}{2000}$	120	—
Mehalla-el-Kobra, " "	4	" $\frac{1}{2000}$	120	—

LIST OF PUBLICATIONS

Title of the Book.	Price. L.E.	Price. Mill.
PUBLIC WORKS MINISTRY.		
A Report upon the Basin of the Upper Nile with proposals for the improvement of that river, 1904 ..	—	600
Irrigation Report for the year 1884	—	100
Report on the Administration of the Irrigation Department, for the years 1891, 1895, 1896 and 1897 .. .. Each	—	250
Report upon the Administration of Public Works Department, for the years 1899 and 1900.. Each	—	250
Report upon the Administration of Public Works Department, for the years 1901, 1902 and 1903 ..	—	300
Note on the Irrigation Works of Egypt and the improvements to be made to them, 1884.	—	100
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Nile Reservoirs Appendices, 1892..	—	120
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Report of the Technical Commission on Reservoirs, 1894	—	300
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